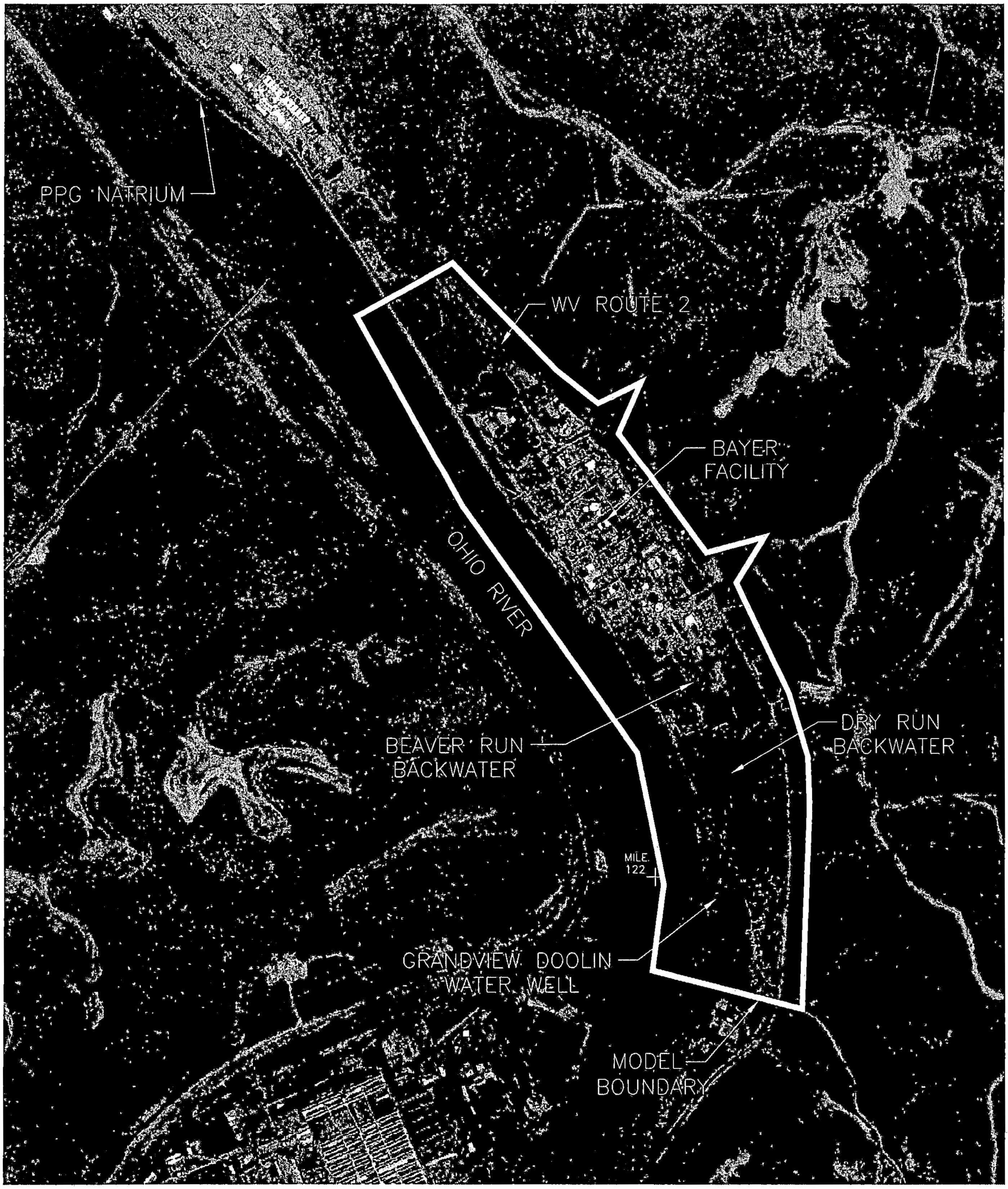
FIGURES



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Plot date: 01-16-2004

MFG consulting scientists, and engineers

REV.:	
PROJ NO:	120299
DATE:	MARCH, 2003
PCP/PC2:	
DRAWN BY:	WPZ
CHECKED BY:	

Bayer

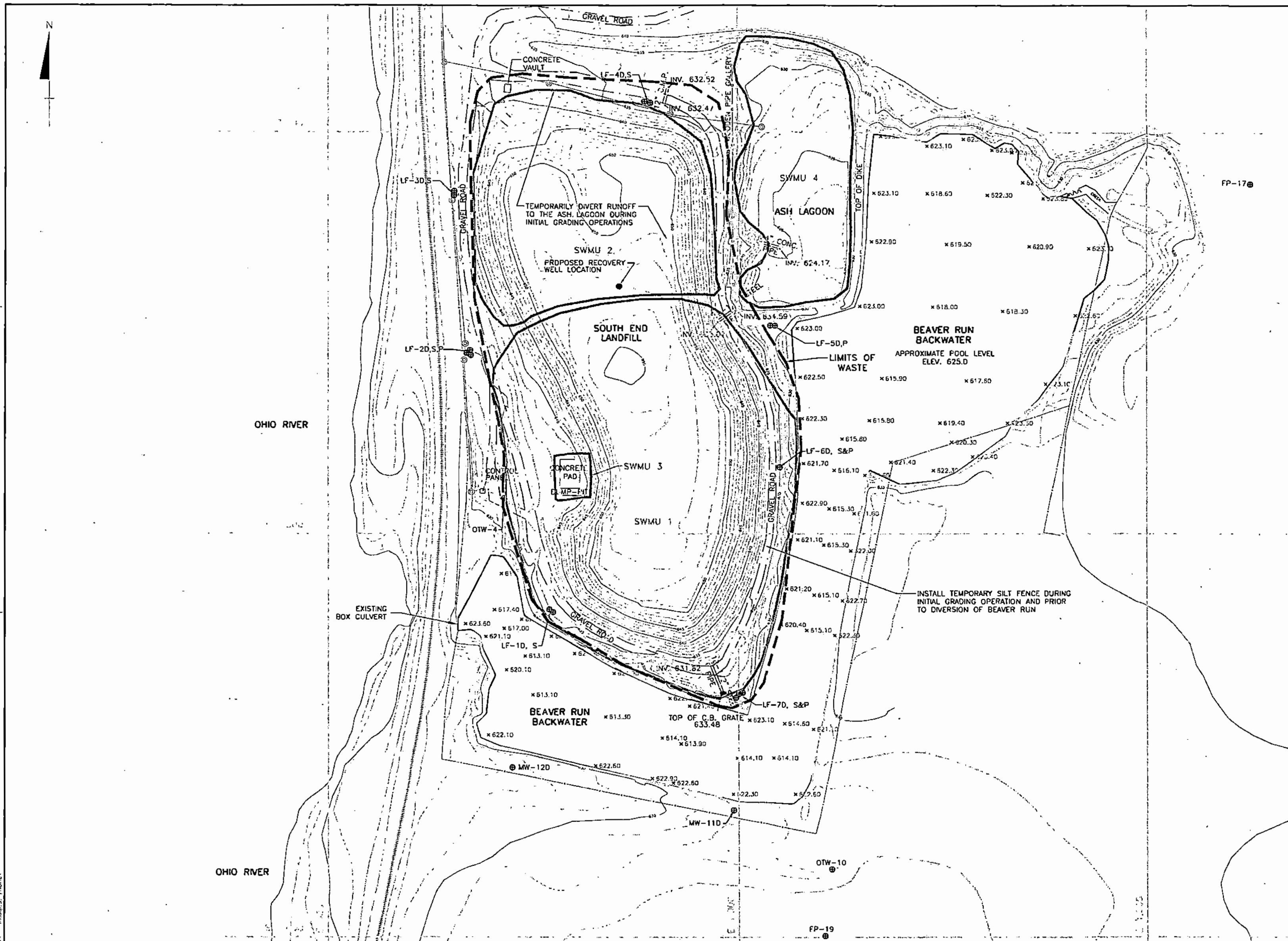
APPROXIMATE SCALE: 1" = 2000'

BAYER CORP.
NEW MARTINSVILLE, WEST VIRGINIA

FIGURE 1-1
SITE PLAN

THE INFORMATION PROVIDED ON THIS DRAWING WAS PRODUCED USING BOTH TECHNICAL INFORMATION AND KNOW HOW. ANY ADAPTATION OR MODIFICATION OF THE INFORMATION OR DRAWING SHALL BE AT THE USER'S SOLE RISK AND WITHOUT LIABILITY OR LEGAL EXPOSURE TO THE ENGINEER.

DRAWING NO. 120299-1-1



LEGEND:

	RAILROAD TRACKS
	FENCE
	EDGE OF WATER
⊕	EXISTING MONITORING WELL
◎	POLE
× 621.0	SUBSURFACE GRADES
	TEMPORARY DIVERSION
— — — —	ESTIMATED LIMITS OF WASTE
———	APPROXIMATE LIMITS OF SWMUs

REFERENCES:

1. AREA INSIDE THE FENCELINE WAS SURVEYED BY PARSONS SURVEYING, HENRY M. PARSONS, LAND SURVEYOR NO.98, 121 GLENVIEW DR, NEW MARTINSVILLE, WEST VIRGINIA 26155. DRAWING PROVIDED "TOPOGRAPHICAL SURVEY FOR MFG, INC., OF THE BEAVER CREEK BACKWATER AREA, AND OLD LANDFILL, ON THE SOUTH END OF THE BAYER CHEMICAL PLANT, IN FRANKLIN DISTRICT, MARSHALL COUNTY, WEST VIRGINIA." DWG NO. 2001-10435, DATED JULY 24, 2001.

2. REMAINING TOPOGRAPHY ADAPTED FROM "TREATMENT, STORAGE, AND DISPOSAL SITES", MOBAY CHEMICAL CORP., DWG NO. D07-9100-G031. PREPARED BY EASTERN MAPPING CO, PGH, PA, ARRIAL FLIGHT DATE 7/9/83.

MFG
consulting scientists and engineers
800 Vinial Street
Pittsburgh, PA 152
Phone (412) 321-2
Fax (412) 321-22

SCALE 60 0 60 FEET

FILE NO: 120299-SP-
PROJECT NO:12029
SHEET 001

NO.	DATE	DESCRIPTION	BY	CHKD.	APPD.
0		FOR CONSTRUCTION			
A		FOR APPROVAL			

REFERENCES TITLE	DRAWING NO.
TOPOGRAPHICAL SURVEY FOR M.F.G. INC. PARSONS SURVEYING	2001-10435
TREATMENT, STORAGE, AND DISPOSAL SITES, MOBAY CHEM. CORP.	D07-9100-G031

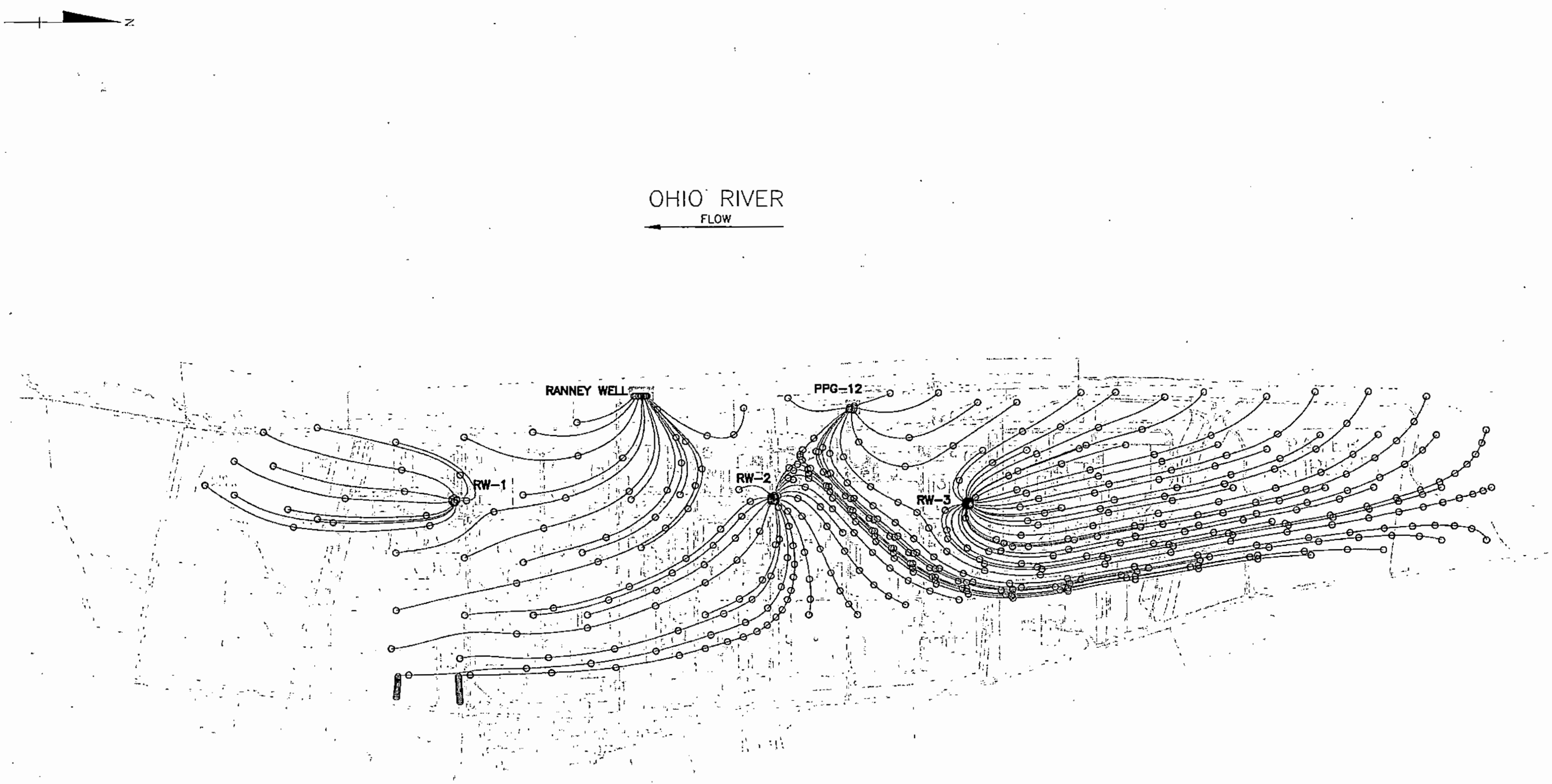
PROJECT LOC.	NEW MARTINSVILLE, WV	
PROJECT NO.		
DESIGN BY		
DES.CHKD.BY		
DRFT. APP.		
DRAWN BY		
DWG.CHKD.BY		

Bayer

NEW MARTINSVILLE WV
SOUTH LANDFILL REMEDIATION
SWMU LOCATIONS

AREA
SCALE 1" = 60'

FIGURE 1-2



NOTE:

PARTICLES WERE SEEDED IN MODEL LAYER 3.

LEGEND:

GROUNDWATER RECOVERY WELL OR SUPPLY WELL

PATHLINE WITH 30 DAY TIME MARKERS

SCALE

600 0 600 FEET

CONFIDENTIAL

MFG
consulting scientists and engineers
800 Vinial Street, Building A
Pittsburgh, Pennsylvania 15212
Phone (412) 321-2278
Fax (412) 321-2283

Bayer

DISCLAIMER

REFERENCE

NO.	REVISIONS	BY	DATE
0	ISSUE FOR REVIEW	-	-

DESIGNED BY:	--
DRAWN BY:	WP
CHECKED BY:	--
APPROVED BY:	--
PCP/PC2:	MFG-STD
VIEW NAME:	
ORIGINATION DATE:	03/16/0
PLOT SCALE:	1:1 OR 1:2
DATE:	JANUARY 2004

BAYER CORPORATION

NEW MARTINSVILLE, WV

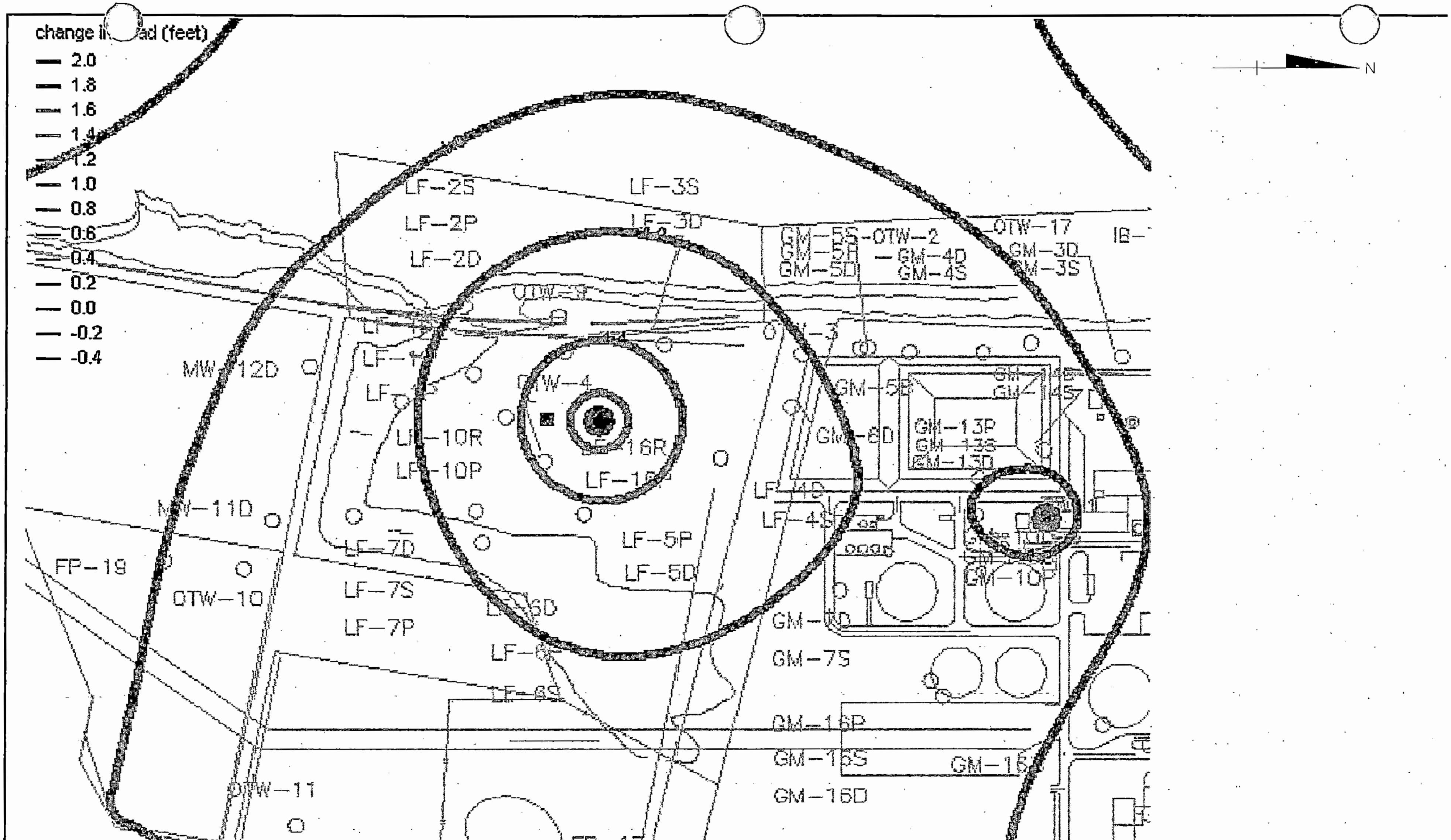
FIGURE 1-3

EXISTING RECOVERY WELLS

DRAWING NO. 120299-1-3

REV.NO. 0

SHEET 1 OF 1



SCALE

300 0 300 FEET

NOTE:

FIELD CONDITIONS ARE EXPECTED TO VARY +/- 0.5 FEET FROM THIS MODEL RESULT.

REFERENCE:

BASEMAP AND WELL LOCATIONS FROM AREIAL SURVEY PROVIDED BY MARKHURD, DATED APRIL, 1993.

BAYER CORPORATION
NEW MARTINSVILLE, WV

FIGURE 2-1
SIMULATED CHANGE IN POTENTIOMETRIC HEAD DUE TO 150 gpm PUMPING AT PROPOSED RECOVERY WELL

PROJECT: 120299	DATE: JANUARY, 2004	
REV:	BY: WPZ	CHECKED:

MFG, Inc.
consulting scientists and engineers

WPZ G:\AutoCAD\ncs\120299 Bayer GW\New Fig\120299-Fig2-1-Alt.dwg 01-30-2004 01:56 pm
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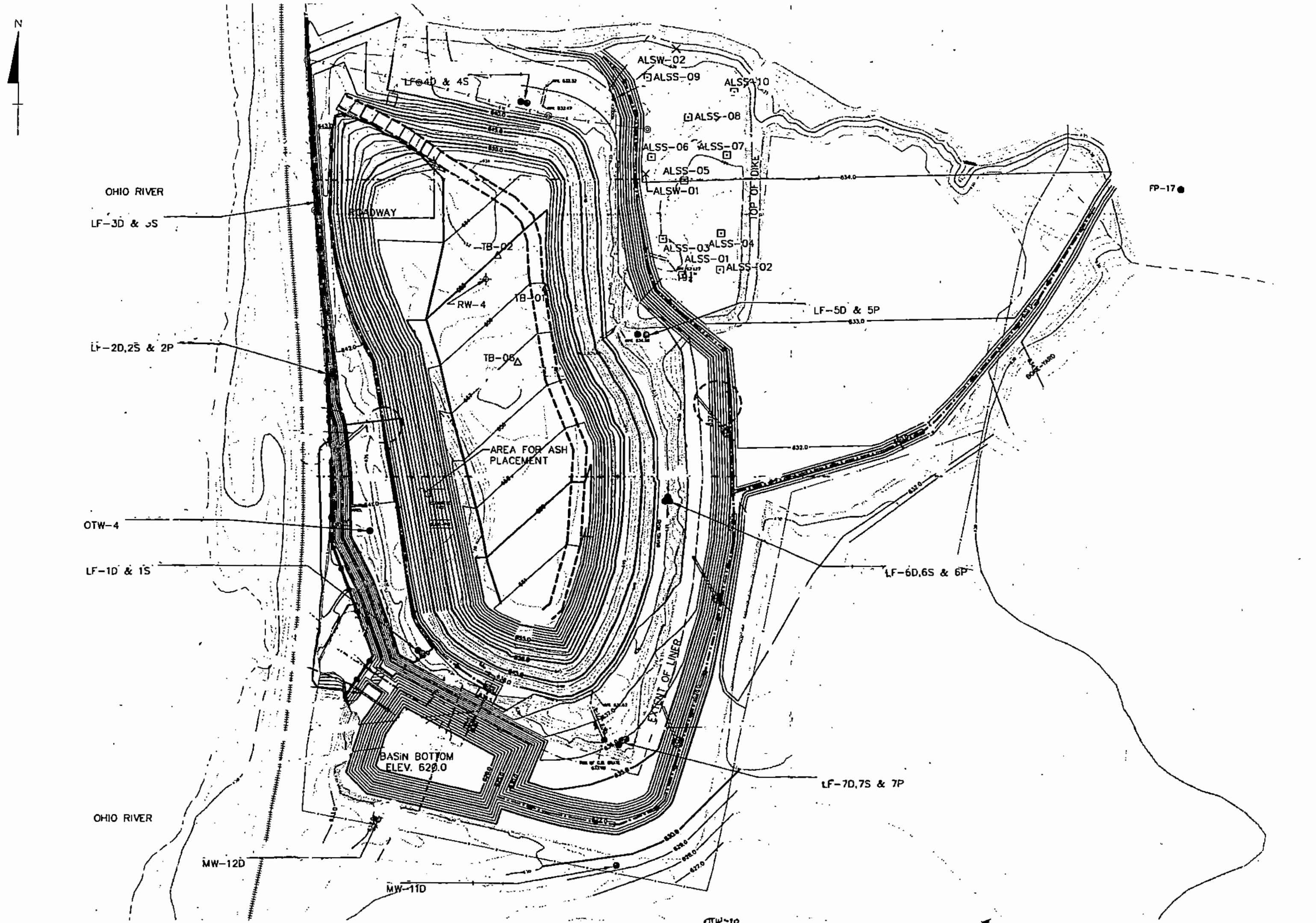
Plot date: 01-30-2004



PLAN VIEW

SCALE
60 0 60 FEET

FP19

LEGEND:

	SILT FENCE
	FINAL 5FT INTERVAL CONTOUR
	FINAL 1FT INTERVAL CONTOUR
	EXISTING 5FT INTERVAL CONTOUR
	EXISTING 1FT INTERVAL CONTOUR
	EXTENT OF LINER
	RAILROAD TRACKS
	FENCE
	EDGE OF WATER
	PROPOSED RECOVERY WELL
	EXISTING MONITORING WELL
	POLE
LF-4D	MONITORING WELL INCLUDED IN SAMPLING PROGRAM
LF-3D	MONITORING WELL USED AS SENTRY WELL DURING PUMPING TEST
TB01	SOIL BORING LOCATIONS DURING PHASE 2 OF RFI
ALSS-01	PROPOSED ASH LAGOON CONFIRMATORY SOIL SAMPLE LOCATIONS
ALSW-01	PROPOSED ASH LAGOON CONFIRMATORY SOIL SAMPLE LOCATIONS

REFERENCES:

1. AREA INSIDE THE FENCELINE WAS SURVEYED BY PARSONS SURVEYING, HENRY M. PARSONS, LAND SURVEYOR NO.98 121 GLENVIEW DR, NEW MARTINSVILLE, WEST VIRGINIA 26155. DRAWING PROVIDED "TOPOGRAPHICAL SURVEY FOR MFG, INC., OF THE BEAVER CREEK BACKWATER AREA, AND OLD LANDFILL, ON THE SOUTH END OF THE BAYER CHEMICAL PLANT, IN FRANKLIN DISTRICT, MARSHALL COUNTY, WEST VIRGINIA. DATED JULY 24, 2001.

2. REMAINING TOPOGRAPHY ADAPTED FROM "TREATMENT, STORAGE, AND DISPOSAL SITES", MOBAY CHEMICAL CORP., DWG NO. D07-9100-G031. PREPARED BY EASTERN MAPPING CO, PGH, PA, ARRIAL FLIGHT DATE 7/9/83.

NOTE:

VEGETATE ALL DISTURBED AREA INCLUDING LANDFILL CAP IN ACCORDANCE WITH SECTION 652 OF WEST VIRGINIA DIVISION OF HIGHWAYS, STANDARD SPECIFICATIONS – ROADS AND BRIDGES INCLUDE TYPE B SEED MIXTURE.

consulting scientists and engineers
800 Vinial Street,
Pittsburgh, PA 15212
Phone (412) 321-2278
Fax (412) 321-2283

FILE NO: 120299-SP-E2.dwg
PROJECT NO:120299

REVISIONS

NO.	DATE	DESCRIPTION	BY	CHKD.	APPD.	NO.	DATE	DESCRIPTION	BY	CHKD.	APPD.
1	07/24/03	FINAL GRADE EDITED FOR 3-FT COVER	MAW	BOC							
0		FOR CONSTRUCTION									
A		FOR APPROVAL									

REFERENCES

TITLE	DRAWING NO.	TITLE	DRAWING NO.
TOPOGRAPHIC SURVEY FOR MFG, INC., PARSONS SURVEYING	2001-10435		
TREATMENT, STORAGE, AND DISPOSAL SITES, MOBAY CHEM CORP	D07-9100-G031		

APPROVALS

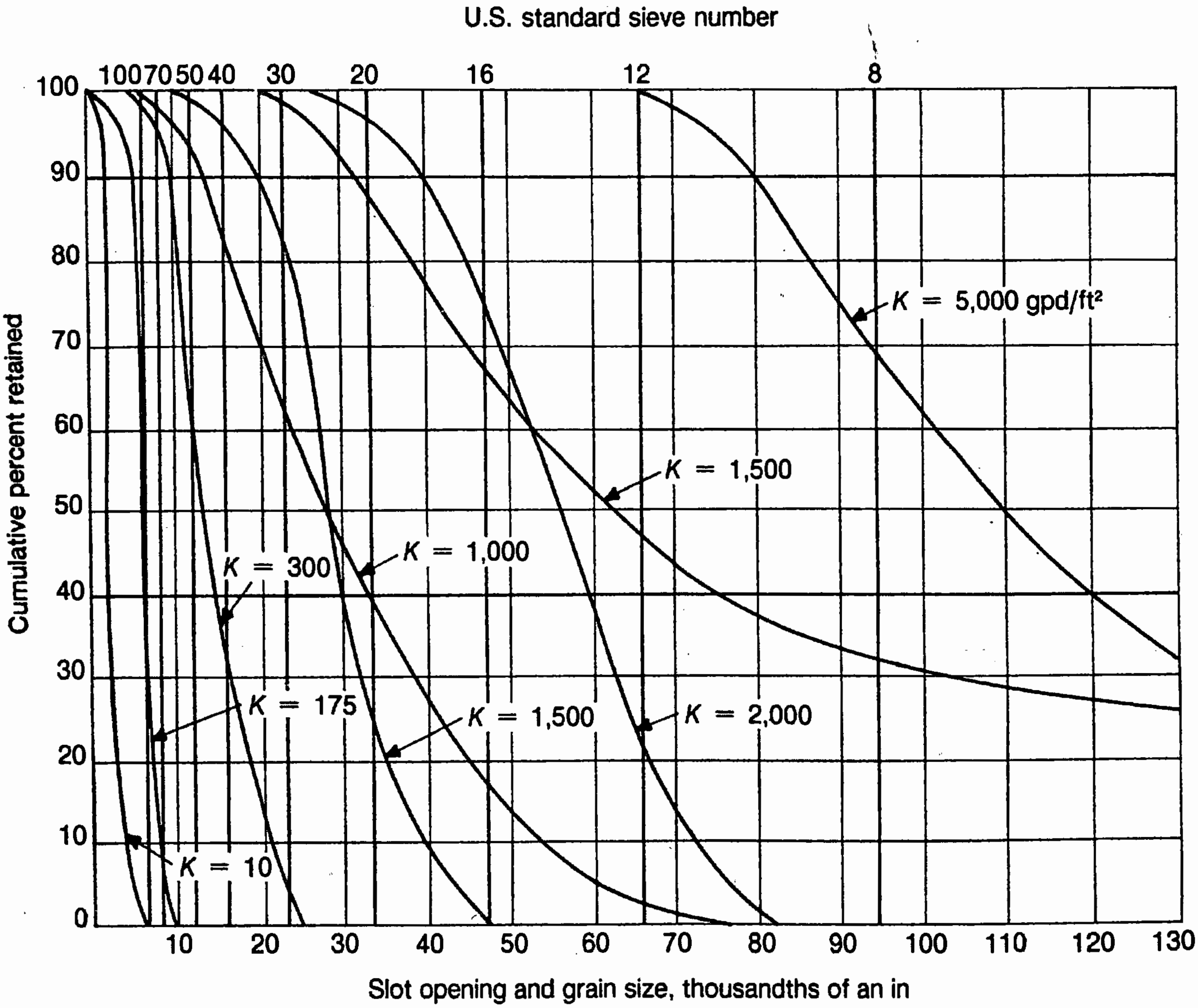
NAME	DATE	NAME	DATE

PROJECT LOC.
PROJECT NO.
DESIGN BY
DES. CHKD BY
DRFT. APP.
DRAWN BY
DWG CHKD. BY

Bayer

NEW MARTINSVILLE WV PLANT
SWMU GROUP A WELL LOCATIONS

AREA
SCALE: 1" = 60'
D
FIGURE 2-2
REV. 1



BAYER CORPORATION
NEW MARTINSVILLE, WV

FIGURE 3-1
GRAM SIZE/SLOT SIZE WITH HYDRAULIC CONDUCTIVITY ESTIMATE (AFTER DRISCOLL, 1987)

PROJECT: 120299	DATE: JANUARY, 2004	
REV:	BY: WPZ	CHECKED:

MFG, Inc.
consulting scientists and engineers

WPZ G:\AutoCAD\ncs\120299 Bayer GW\Remediation\120299-Remediation-Fig3-1.dwg 01-15-2004 06:08 pm
Xrefs: [none]
Images: Form.tif
Plot time: 06:08 pm
Plot date: 01-15-2004

TABLES

Table 2-1
Comparison of Slot Size and Gallons per Minute for a 20-foot Section of 10-inch ID Screen

Standard Slot Size (inches)	Open Area in Screen (in^2/ft)(1)	Discharge from a 1-foot Section of Screen in gpm(2) Entrance Velocity=0.1 ft/sec(3) (in2/ft)(0.3117)	Discharge from a 20-foot Section of Screen in gpm with Entrance Velocity of 0.1 ft/sec	
			Open	**50% Blocked**
0.01	41	12.78	255.59	127.80
0.02	72	22.44	448.85	224.42
0.03	100	31.17	623.40	311.70
0.04	122	38.03	760.55	380.27
0.04	143	44.57	891.46	445.73
Johnson Well Screen(4)				
0.03	83	25.87	517.42	258.71
0.04	103	32.11	642.10	321.05

Notes (1) Square inches per foot

(2) Gallons per minute

(3) Feet per second

(4) All figures from this piont to the bottom of the Table refer to specifications for Johnson Well Screens

Table 4-1
Monitoring/Recovery Wells and Sampling Schedule
Bayer, New Martinsville, WV

Well Number	Diameter (inches)	Sampling Frequency	Quarters	
			1st & 3rd	2nd & 4th
FP-4	2	Semi-Annually	Yes	No
FP-12	2	Semi-Annually	Yes	No
FP-13	2	Semi-Annually	Yes	No
FP-16	2	Semi-Annually	Yes	No
FP-17(2)	2	Quarterly	Yes	Yes
FP-19(2)	2	Quarterly	Yes	Yes
GM-5S	2	Semi-Annually	Yes	No
GM-5D	2	Semi-Annually	Yes	No
GM-5B	2	Semi-Annually	Yes	No
GM-16S	2	Semi-Annually	Yes	No
GM-16D	2	Semi-Annually	Yes	No
LF-1S	2	Semi-Annually	Yes	No
LF-4S	2	Semi-Annually	Yes	No
LF-4D	2	Semi-Annually	Yes	No
MW-4S	2	Semi-Annually	Yes	No
MW-4D	2	Semi-Annually	Yes	No
MW-7S	2	Semi-Annually	Yes	No
MW-9D	2	Semi-Annually	Yes	No
MW-10S	2	Semi-Annually	Yes	No
MW-11D(2)	2	Quarterly	Yes	Yes
MW-12D(2)	2	Quarterly	Yes	Yes
MW-13S	2	Semi-Annually	Yes	No
MW13D	2	Semi-Annually	Yes	No
MW-14	2	Quarterly	Yes	Yes
MW-15	2	Quarterly	Yes	Yes
RW-1		Semi-Annually	Yes	No
RW-2A		Semi-Annually	Yes	No
RW-3A		Semi-Annually	Yes	No

Notes [shaded] = Monitoring wells around South Landfill

(1) ft-bgs = feet below ground surface. All figures measured prior to final grade of Landfill cover.

(2) These monitoring wells are sampled annually for dioxin as well as the analytes list in Table 4-3

Table 4-2
Existing Monitoring Wells
South Landfill, Bayer, New Martinsville, WV

Monitoring Well	Total Depth (feet)	Elevaltion (ft-MSL)[2] Ground	[1]TOC_{PVC}	Screened Interval (ft-bgs)[3] From	To	Screen Length (feet)	Final Grade (ft-MSL)	Casing Extension Required	Transducer Installation	Expected Drawdown (feet)	Monitoring Network Semi-Annual	Quarterly
LF-1S	40	636.05	637.84	30	40	10	640	4.66			X	
LF-1D	64	636.12	637.54	39	64	25	640	4.96	X	1.2		
LF-2P	18	634.55	636.38	8	18	10	638	4.12				
LF-2S	40	634.72	636.62	30	40	10	639	4.88				
LF-2D	64	634.89	636.62	39	64	25	639	4.88	X	1.5		
LF-3S	43	637.53	639.49	18	43	25	641	4.01				
LF-3D	68	637.73	639.65	43	68	25	641	3.85	X	1.4		
LF-4S	34	633.27	635.14	14	34	20	638.5	5.86			X	
LF-4D	60	633.64	635.51	35	60	25	638.5	5.49	X	1.3	X	
LF-5P	17	632.3	633.61	7	17	10	638.5	7.39				
LF-5D	59	632.52	634.1	34	59	25	638.5	6.9	X	1.3		
LF-6P	15	630.89	632.15	5	15	10	638.5	8.85				
LF-6S	35	630.73	632.6	25	35	10	638.5	8.4				
LF-6D	58	630.74	632.61	33	58	25	638.5	8.39	X	1.3		
LF-7P	15	630.56	632.14	5	15	10	636	6.36				
LF-7S	35	630.42	632.29	25	35	10	636	6.21			X	
LF-7D	60	631.45	632.89	35	60	25	636	5.61	X	1.2		
OTW-4	N/A[4]	633.26	635.46	N/A	N/A	N/A	640.8	7.84	X	1.3		
OTW-10	N/A	634.1	636.3	N/A	N/A	N/A	634.1	0				
MW-11D	57	628.04	630.21	25	55	30	629.25	1.54				X
MW-12D	59	632.84	634.65	37.5	57.5	20	631.5	-0.65				X
FP-17	49	636.11	637.94	14	49	35	636.11	0				X
FP-19	55	625.06	626.73	15	55	40	625.06	0				X

Notes
(1) TOC_{PVC}=Top of Casing (PVC)
(2) ft-MSL=feet above mean sea level
(3) ft-bgs=feet below ground surface
(4) N/S=Not Available

Table 4-3
Bayer, New Martinsville, WV
Groundwater Analyte List

Conventionals		*Metals*
Conductivity		Antimony
pH		Cadmium
Sulfate		Chromium
Temperature		Lead
Total Dissolved Solids		Nickel
Total Organic Carbon		
	Semivolatiles	
1,2,3-Trichlorobenzene	4-Chlorophenylphenyl ether	Fluoranthene
1,2,4,5-Tetrachlorobenzene	4-Nitroaniline	Fluorene
1,2,4-Trichlorobenzene	4-Nitrophenol	Heptachlor
1,2-Dichlorobenzene	5-Nitro-o-toluidine	Hexachlorobenzene
1,3-Dichlorobenzene	7,12-dimethylbenz[a]anthracene	Hexachlorobutadiene
1,4-Dichlorobenzene	Acenaphthene	Hexachlorocyclopentadiene
1-Chloronaphthalene	Acenaphthylene	Hexachloroethane
1-Methylnaphthalene	Acetophenone	Indeno[1,2,3-cd]pyrene
1-Naphthylamine	Aniline	Isophorone
2,3,4,6-Tetrachlorophenol	Anthracene	m,p-Cresol
2,3-Dichloroaniline	Azobenzene	Methyl methane sulfonate
2,4,5-Trichlorophenol	Benzidine	m-Nitrotoluene
2,4,6-Trichlorophenol	Benzo(a)anthracene	m-Toluidine
2,4-Dichlorophenol	Benzo(k)fluoranthene	Naphthalene
2,4-Dimethylphenol	Benzo[a]pyrene	Nitrobenzene
2,4-Dinitrophenol	Benzo[b]fluoranthene	N-Nitrosodibutylamine
2,4-Dinitrotoluene	Benzo[ghi]perylene	N-Nitrosodimethylamine
2,4-Toluenediamine	Benzoic Acid	N-Nitrosodiphenylamine
2,6-Dichlorophenol	Benzyl Alcohol	N-Nitrosodipropylamine
2,6-Dinitrotoluene	Benzyl butyl phthalate	N-Nitrosopiperidine
2-Chloronaphthalene	Bis(2-chloroethoxymethane)	o,p-Toluidine
2-Chlorophenol	Bis(2-chloroethyl ether)	o-Cresol
2-Methylnaphthalene	Bis(2-chloroisopropyl)ether	o-Nitrotoluene
2-Naphthylamine	Bis(2-ethylhexyl) phthalate	p-Chloroaniline
2-Nitroaniline	Bisphenol A	p-Dimethylaminoazobenzene
2-Nitrodiphenylamine	Carbazole	Pentachlorobenzene
2-Nitrophenol	Chrysene	Pentachloronitrobenzene
2-Picoline	Cyclohexanone	Pentachlorophenol
3,3'-Dichlorobenzidine	Dibenz[a,h]anthracene	Phenacetin
3-Methylcholanthrene	Dibenzofuran	Phenanthrene
3-Nitroaniline	Diethyl Phthalate	Phenol
4,4' Methylenedianiline	Dimethylphthalate	p-Nitrotoluene
4,6-Dinitro-o-cresol	Di-n-butyl phthalate	Pyrene
4-Aminobiphenyl	Di-n-octyl phthalate	Pyridine
4-Bromophenyl phenyl ether	Ethyl Methane Sulfonate	Trimethylphosphate
4-Chloro-m-cresol	Ethyl Methane Sulfonate	Triphenylphosphate

Continued on next page

Table 4-3
Bayer, New Martinsville
Groundwater Analyte List (cont.)

Volatiles		
1,1,1,2-Tetrachloroethane	Acrolein	Methyl Acrylate
1,1,1-Trichloroethane	Acrylonitrile	Methyl Ethyl Ketone
1,1,2,2-Tetrachloroethane	Benzene	Methyl Isobutyl Ketone
1,1,2-Trichloroethane	Bromobenzene	Methyl Methacrylate
1,1-Dichloroethane	Bromochloromethane	Methylene Chloride
1,1-Dichloroethene	Bromodichloromethane	Methyl-Tert-Butyl Ether
1,1-Dichloropropene	Bromoform	Naphthalene
1,2,3-Trichlorobenzene	Bromomethane	n-Butylbenzene
1,2,3-Trichloropropane	Carbon Disulfide	Nitrobenzene
1,2,4-Trichlorobenzene	Carbon Tetrachloride	n-Propylbenzene
1,2,4-Trimethylbenzene	Chloroacetonitrile	o-Xylene
1,2-Dibromo-3-Chloropropane	Chlorobenzene	Pentachloroethane
1,2-Dibromoethane	Chloroethane	p-Isopropyltoluene
1,2-Dichlorobenzene	Chloroform	Propionitrile
1,2-Dichloroethane	Chloromethane	sec-Butylbenzene
1,2-Dichloropropane	cis-1,2-Dichloroethene	Styrene
1,3,5-Trimethylbenzene	cis-1,3-Dichloropropene	tert-Butylbenzene
1,3-Dichlorobenzene	Dibromochloromethane	Tetrachloroethene
1,3-Dichloropropane	Dibromomethane	Tetrahydrofuran
1,4-Dichlorobenzene	Dichlorodifluoromethane	Toluene
1-Chlorobutane	Diethyl Ether	trans-1,2-Dichloroethene
2,2-Dichloropropane	Ethyl Methacrylate	trans-1,3-Dichloropropene
2-Chloroethylvinyl Ether	Ethylbenzene	trans-1,4-Dichloro-2-Butene
2-Chlorotoluene	Hexachlorobutadiene	Trichloroethene
2-Hexanone	Hexachloroethane	Trichlorofluoromethane
2-Nitropropane	Iodomethane	Vinyl Acetate
3-Chloro-1-Propene	Isopropylbenzene	Vinyl Chloride
4-Chlorotoluene	m & p Xylene	
Acetone	Methacrylonitrile	

APPENDICES

APPENDIX A

RECOVERY WELL LOGS – GERAGHTY & MILLER

GERAGHTY & MILLER, INC.
Ground-Water Consultants

SAMPLE/CORE LOG

Boring/Well (RW-1) OW-1 Project/No. Mobay / RC458MC3 Page 1 of 2

Site Location New Martinsville WV Drilling Started 11/27/85 Drilling Completed 12/3/85

Total Depth Drilled 54 (feet)

Hole Diameter 9 (inches) Type of Sample/ Coring Device Split Spoon

Length and Diameter of Coring Device 2" O.D., 18" long Sampling Interval Variable feet

Drilling Fluid Used None Drilling Method Hollow Stem Auger

Drilling Contractor Penna Drilling Co. Driller R. Yost Helper H. Haflin

Prepared By T. Retrosky Hammer Weight 140# Hammer Drop 30 inches

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 Inches	Sample/Core Description
22.0	23.5	1.1	9-12-20	Clay, some silt, trace gravel and sand, moist, yellowish-brown, moist, chem. odor
23.5	25.0	1.2	9-4-6	Silt and Clay, little sand, trace gravel, grading to wet, brown, chem. odor
25.0	26.5	0.0	4-6-10	No Recovery
26.5	28.0	1.3	12-17-18	Clay, some silt, little medium gravel, little-trace sand, wet brown (1.0'). Gravel, medium angular, wet black (0.3')
28.0	29.5	1.0	3-6-8	Clay and Gravel, some sand, wet, black (0.4'). Sand, fine to coarse, little-trace silt, reddish-brown, very moist
				12/3/85 - Water level about 21-22' - Tape/M-Scope won't work well - too cold
29.5	31.0	0.8	3-7-9	Sand, medium to coarse, little-trace silt, trace clay, reddish-brown, wet

GERAGHTY & MILLER, INC.
Ground-Water Consultants

SAMPLE/CORE LOG (Cont.d)

Boring/Well OW-1 (RW-1)

Page 2 of 2

Prepared By T. Retrosky

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 Inches	Sample/Core Description
31.0	32.5	1.0	15-35-35	Sand, medium to coarse, trace silt, trace gravel, reddish-brown
32.5	34.0	0.4	18-20-30	Sand, medium to coarse, trace silt, reddish-brown, wet
34.0	35.5	1.0	19-25-30	Same
35.5	37.0	0.8	9-18-20	Grading to trace gravel
37.0	38.5	0.8	17-17-26	Grading to no gravel
38.5	40.0	0.0	—	Wash in augers will not allow sampling Green Sandstone fragment in spoon nose
40.0	41.5	1.0	25-30-32	Sand, medium to coarse, and [illegible] Gravel, fine to coarse, brown, wet
43.0	44.5	0.0	11-19-25	Possibly pushing lg. gravel - No Recovery
46.0	47.5	0.6	15-25-28	Possibly wash - Sand, medium to coarse, little to none fine gravel, brown, wet
[illegible]0	51.5	0.4	17-22-24	Sand, medium to coarse, and Gravel, fine to medium, brown, wet
52.0	53.5	0.0	8-7-6	No Recovery

GERAGHTY & MILLER, INC.
Ground-Water Consultants

SAMPLE/CORE LOG

Boring/Well RW-21 Project/No. Mobay Page 1 of 3

Site Location New Martinsville, WV Drilling Started 11/6/85 Drilling Completed 11/6/85

Total Depth Drilled 51.5 (feet)

Hole Diameter 9 (inches) Type of Sample/Coring Device Grab/Split Spoon

Length and Diameter of Coring Device 2" O.D., 18" Long Sampling Interval Variable feet

Drilling Fluid Used None Drilling Method Hollow Stem Auger

Drilling Contractor Penna Drilling Co. Driller Bob Yost Helper H. Heflin

Prepared By T. Ratvasky Hammer Weight 140# Hammer Drop 30 Inches

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 Inches	Sample/Core Description
SURFACE				Limestone Gravel
0.0	5.0	GRAB	—	Clay, some silt, occasional fine gravel, brown, moist.
5.0	10.0	GRAB	—	Grading to little to some (10%) fine to medium gravel.
10.0	15.5	GRAB	—	Same to approx 13.0-14.0 ft. Remainder= Clay, little silt, trace to no gravel, reddish brown, moist; lighter in color and heavier in clay than above
15.5	17.0	1.3'	10-6-10	Clay, little silt, reddish brown, moist, many pink, medium, prominent mottles, particularly along visible soil pores, trace black plant matter
17.0	18.5	0.05'	24-18-23	Sand, fine ~~to medium~~; some silt; reddish-brown, moist - rock in spoon nose -
18.5	20.0	1.0	5-8-11	Grading to no silt

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Ground-Water Consultants

SAMPLE/CORE LOG (Cont.d)

Boring/Well RW-2

Prepared By T. Ratvasky

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 inches	Sample/Core Description
20.0	21.5	1.5	8-11-10	Sand, fine, and Silt, little clay, reddish-brown, moist (1.0 foot) Sand, fine to medium, trace to no silt, reddish-brown, moist (3 inches).
21.5	23.0	1.5	3-6-6	Sand, fine, some to and Silt, trace clay, occasional lens of Sand, fine to medium, brown, moist.
23.0	24.5	1.3	3-4-3	Sand, fine, some silt, brown, moist changing to wet
24.5	26.0	1.4	3-7-9	Sand, fine to medium, little to no silt, very moist; appears wet, as is upper part of sample
26.0	27.5	1.0	3-5-7	Sand, fine to coarse, little to no silt, brown, v. moist-wet
27.5	29.0	1.3	5-7-7	Sand, fine to medium, brown, wet
29.0	30.5	1.4	5-9-9	Same
35.0	36.5	1.0	7-22-75	Sand, fine to coarse, and Gravel, fine to coarse, trace to no silt, brown, wet
40.0	41.5	0.5	12-25-58	Sand, medium to coarse, and Gravel, fine

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Ground-Water Consultants

SAMPLE/CORE LOG

Boring/Well OW-2 (RW-3) Project/No. Mobay Page 1 of 3

Site Location New Martinsville Drilling Started 12/23/85 Drilling Completed 12/30/85

Total Depth Drilled 52.5 (feet)

Hole Diameter 11"/6" (inches) Type of Sample/Coring Device Split Spoon

Length and Diameter of Coring Device 2" O.D. 18" Long Sampling Interval Continuous feet

Drilling Fluid Used Plant Water Drilling Method 5' Driven Casing; 10" Augers

Drilling Contractor Penna. Drilling Co. Driller R. Yost Helper H. Heflin

Prepared By T. Ratvasky Hammer Weight 140# Hammer Drop 30 inches

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 inches	Sample/Core Description
15.0	16.5	1.5	6-8-9	Clay, some silt, little fine sand, reddish-brown, moist, with pink and gray common, medium mottles around visible pores.
16.5	18.0	1.5	12-11-15	Same (0.3'). Sand, some to and clay, little silt, (0.6'). Sand, little to some silt, moist, reddish-brown (0.6')
18.0	19.5	0.7	4-8-10	Sand, fine to medium, reddish-brown, moist
19.5	21.0	1.5	6-6-8	Grading to trace silt
21.0	22.5	1.5	4-6-6	Same
22.5	24.0	1.5	4-4-5	Same
24.0	25.5	1.5	6-6-6	Same

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SAMPLE/CORE LOG (Cont.d)

Boring/Well OW-2 (RW-3)

Page 2 of 3

Prepared By T. Ratvasky

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 inches	Sample/Core Description
25.5	27.0	1.5	2-2-2	Silt and Sand, fine, reddish-brown, wet
27.0	28.5	1.5	2-3-7	Sand, fine to medium, trace-no silt (0.6'). Silt little clay, some fine sand (0.4'). Sand, fine to coarse, all reddish-brown, wet
28.5	30.0	1.5	4-4-6	Same, with lenses of Sand, little silt
30.0	31.5	1.5	2-3-5	Sand Fine to coarse, trace silt, reddish-brown, wet
31.5	33.0	1.2	10-10-14	Same
33.0	34.5	0.9	14-11-13	Sand, medium to fine, little to some Gravel, fine, little-trace silt, brown, wet
34.5	36.0	1.0	13-18-27	Sand, medium to fine, some to and Gravel, fine to medium, little silt, brown, wet
39.0	40.5	0.5	14-11-12	Gravel, fine, and to some Sand, medium to coarse, brown, wet. Wash is fine gravel.
40.5	42.0	0.6	19-21-23	Gravel fine, some coarse Sand, occasional coarse gravel, trace silt, brown, wet.
42.0	43.5	0.4	25-19-18	Gravel, Fine and Sand, medium to coarse, trace silt, occasional large gravel fragment, brown, wet. Could not prevent flowing sand

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SAMPLE/CORE LOG (Cont.d)

Boring/Well (RW-3) OW-2

Prepared By T. Ratvasky

Sample/Core Depth (feet below land surface) From	To	Core Recovery (feet)	Time/Hydraulic Pressure or Blows per 6 inches	Sample/Core Description
43.5	45.0	0.3	12-11-11	Grading to little silt and clay
45.0	46.5	0.5	25-27-21	Same
48.0	49.5	0.3	25-23-24	Gravel, fine, and Sand, fine to coarse, little silt and clay, brown, wet
49.5	51.0	0.0(1.5)	11-15-12	No Recovery - all wash-up: fine gravel and coarse sand, gravel broken up by roller bit. Possibly overdrill, but spoon was resting @ proper starting point
51.0	52.5	0.3	12-10-7	Gravel, medium, and Sand, medium to coarse, some fine gravel, trace silt, brown, wet.

APPENDIX B

SELECT PHASE 2 RFI SOIL BORING LOGS

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME: Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING: SM001-TB06
BORING LOCATION: SWMU 001	DRILLING (ft-bgs): N/A	G.S. ELEV.: 653.486
DRILLING FIRM: Pennsylvania Drilling Co.	WELL LEVEL (ft-msl): N/A	CASING ELEV.: N/A
DRILLING METHOD: Hollow Stem Auger/Split Spoon	NORTHING: 812.24116	START DATE: 10/29/96
LOGGED BY: B. Squire	EASTING: -3253.05424	FINISH DATE: 10/31/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
			5						
1			6		SM001TB06-0002	Brown clay soil, sandstone rock fragments, organic matter, little sand wood, stiff, nonplastic, damp, (fill)			1
			11						
2		50	15	0		Granular iron oxide, med. dense to loose, damp, (fill)			2
			13			Black-red grading to black iron oxide, occ sandstone rock fragments, med. dense, damp, (fill)			
3			17						3
			18						
4		50	20	0	SM001TB06-0305				4
			11						
5			12						5
			11						
6		50	9	0					6
			13						
7			15						7
			5						
8		50	6	0					8
			2						
9			3						9
			2			As above, black-brown, med. dense to loose, damp grading to moist			
10		50	2	0					10
			10						
11			14			Gray-brown sand, gravel, rock fragments, loose to med. dense, damp, (fill)			11
			10						
12		75	7	0		Black clay/silt, some whiteand tan rock fragments, stiff, nonplastic, damp, (fill)			12
			10						
13			10			Red and black iron oxide, loose, damp, (fill)			13
			17			Gravel, rock fragments, dense, dry to damp, (fill)			
14		50	44	0					14
			49			Red iron oxide, few yellow mottles, med. dense, damp, (fill)			
15			41						15
			19			Black iron oxide, soft/loose, moist grading to dry, (fill)			
16		50	13	0					16
			9						
17			7						17

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM001-TB06
BORING LOCATION SWMU 001	DRILLING (ft-bgs) N/A	G.S. ELEV. 653.486
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 812.24116	START DATE 10/29/96
LOGGED BY B. Squire	EASTING -3253.05424	FINISH DATE 10/31/96

DEPTH	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	REMARKS
17–18	<25	10, 13			As above, little green-brown clay, occ. rock fragments, damp to dry	
18–19		5, 7			Black and red iron oxide, soft, moist, (fill)	
19–20	25	8, 10	0		Brown clay and well rounded gravel, little fine sand, loose, damp, (fill)	
20–22	75	wr/6, 2, 2, 7	>1999	SM001TB06-2022	Brown sandy clay, few rock fragments, well rounded gravel, occ. black mottles, soft, sl. plasticity, moist, (fill)	
22–23.5					Black iron oxide, occ. rock fragments, loose, saturated, (fill)	
23.5–24	50		82.4		Rock fragments, fine sand, some brown clay, wire debris, med. dense to dense, damp, (fill)	
24–30				SM001TB06-2430	Hydropunch perched water sample	
30–30.5		9, 7			V. fine to fine sand, few red inclusions, loose, saturated, (fill)	
30.5–32	75	10, 10	3.6		Gray-brown and black clay, little v. fine sand, soft to med. dense, med. plasticity, damp, (fill)	
32–34	75	10, 13, 14, 14	0			

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM001-TB06
BORING LOCATION SWMU 001	DRILLING (ft-bgs) N/A	G.S. ELEV. 653.486
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 812.24116	START DATE 10/29/96
LOGGED BY B. Squire	EASTING -3253.05424	FINISH DATE 10/31/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
			4			Red-brown v. fine sandy clay, occ. well rounded gravel, little gray mottles, piece of latex glove, med. stiff, med. to high plasticity, (fill)			
35			6						35
			10						
36		100	14	0					36
			9						
37			15						37
			15						
38		100	15	0					38
			4						
39			6			As above, damp to moist			39
			10						
40		100	10	0					40
			4						
41			6			As above, damp with saturated zones			41
			10						
42		100	12	0					42
			7						
43			6		SM001TB06-4244	As above grading to v. fine sand and clay, v. soft grading to med. stiff, non grading to high grading to low plasticity, saturated grading to damp			43
			8						
44		100	10	0					44
			5						
45			7						45
			7			Red-brown v. fine to fine sand and clay, grading to red-brown v. fine to fine sand, some clay, med. dense, moist to wet, (CL/SC)			
46		100	8	0					46
			6						
47			8						47
			10						
48		100	11	0					48
			3			Gray-black v. fine to fine sand, little clay, med. dense, moist, (SC)			
49			6						49
			7						
50		75	7	0					50
			5			Gray-brown v. fine to fine sand, loose, moist to wet, (SP)			
51			7						51

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS — BORING LOG

PROJECT NAME: Bayer Corp., New Martinsville, WV	WATER LEVELS		BORING: SM001-TB06
BORING LOCATION: SWMU 001	DRILLING (ft-bgs): N/A		G.S. ELEV.: 653.486
DRILLING FIRM: Pennsylvania Drilling Co.	WELL LEVEL (ft-msl): N/A		CASING ELEV.: N/A
DRILLING METHOD: Hollow Stem Auger/Split Spoon	NORTHING: 812.24116		START DATE: 10/29/96
LOGGED BY: B. Squire	EASTING: -3253.05424		FINISH DATE: 10/31/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
			12			Black v. fine to coarse sand, fine to med. well rounded gravel, loose to med. dense, moist. (SW)			
52		100	24	0					52
			23						
53			37						53
			48						
54		50	66	0					54
			37						
55		100	70	0		Drilled interval			55
56									56
			31			Fine to coarse sand and fine to med. well rounded gravel, dense, wet to saturated, (SW)			
57			34		SM001TB06-5658				57
			26						
58		75	17	0					58
			15			As above, gray-black grading to red-brown, little silt, med. dense, saturated			
59			17						59
			18						
60		100	11			Hydropunch groundwater sample			60
61									61
62									62
63					SM001TB06-6065				63
64									64
65						Bottom of boring 65 ft			65
66									66
67									67
68									68

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME: Bayer Corp., New Martinsville, WV
BORING LOCATION: SWMU 002
DRILLING FIRM: Pennsylvania Drilling Co.
DRILLING METHOD: Hollow Stem Auger/Split Spoon
LOGGED BY: P. Torres

WATER LEVELS
DRILLING (ft-bgs): 19, 51
WELL LEVEL (ft-msl): N/A

NORTHING: 925.62394
EASTING: -3138.85019

BORING: SM002-TB01
G.S. ELEV.: 650.118
CASING ELEV.: N/A
START DATE: 6/25/97
FINISH DATE: 6/26/97

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
0–1	X				SM002TB01-0001	Brown, sandy, SILT, dry (fill)			0–1
1–3						Drilled interval			1–3
3–5	X		5, 5, 6, 12		SM002TB01-0305	Dark brown, sandy SILT, some rocks, pieces of plastic, dry to damp (fill)			3–5
5–7	X	40	6, 7, 5, 6			Dark brown, IRON OXIDE, brown silty clay with yellow and red flakes, white sandy material with some gravel, dry to damp (fill)			5–7
7–9	X	30				Brown, sandy SILT with gravel, sticky, white material with fine fibers, dry to damp (fill)			7–9
9–11	X	30	5, 4, 10, 5			Light gray, gravelly, SAND, dry (fill)			9–11
11–13	X	30	3, 2, 2, 1			Dark brown, fine silty material, some yellow foam-like material, dry to damp (fill)			11–13
13–15	X	40	1, 3, 6, 1		SM002TB01-1315	Dark brown, IRON OXIDE, gray-brown, silty clay with yellow-gray, hard, flakey material with some gravel, damp (fill)			13–15
15–17	X	95	5, 11, 16, 13			Brown-black, IRON OXIDE, moist (fill)			15–17
17–19	X	90	11, 9, 10, 7			As above, moist to wet			17–19
19–20	X		1, 1/12			Dark brown, IRON OXIDE, some silty material with red flakes, wet (fill)			19–20

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB01
BORING LOCATION SWMU 002	DRILLING (ft-bgs) 19, 51	G.S. ELEV. 650.118
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 925.62394	START DATE 6/25/97
LOGGED BY P. Torres	EASTING -3138.85019	FINISH DATE 6/26/97

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
21		25	1						21
			2			Red-brown silty material, shards of plastic, wet (fill)			
22			7						22
			25						
23		25	50						23
			1			Dark brown-red, silty material, some silty clay and gravel, pieces of plastic sheeting, wet (fill)			
24			1						24
			1						
25		30	7						25
			4			Dark brown-red, silty material, some gravel, pieces of synthetic woven material, wet (fill)			
26			4						26
			4						
27			4			Red-brown, SILT and SAND, some gravel, wet (fill)			27
28									28
29		30							29
			1/12			Layered brown-black and brown, SLUDGE, moist to wet (fill)			
30					SM002TB01-2931				30
			1/12						
31		80		100					31
			5			Brown, SLUDGE, some brown-black, silty material with red flakes and yellow-brown streaks, angular shard material, moist to wet (fill)			
32			2		SM002TB01-3133				32
			1						
33		70	1	40					33
			5			Layered brown-black and brown, SLUDGE, wet (fill)			
34			1						34
			1						
35		90	2	20		As above			35
			3						
36			1		SM002TB01-3537				36
			1						
37			3	>100		As above, pieces of black, angular, shard material			37
			2						
38			3		SM002TB01-3739				38
			2						
39		90	2	>100		As above			39
					SM002TB01-3941				
40									40

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB01
BORING LOCATION SWMU 002	DRILLING (ft-bgs) 19, 51	G.S. ELEV. 650.118
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon		START DATE 6/25/97
LOGGED BY P. Torres	NORTHING 925.62394	FINISH DATE 6/26/97
	EASTING -3138.85019	

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
	X			20	SM002TB01-3941				
41	X					As above, piece of wood			41
42	X				SM002TB01-4143				42
43	X		1	20		As above			43
44	X		1 2						44
45	X	90	1 2			As above			45
46	X		3 6			Light gray, gravelly, SAND, damp (fill)			46
47	X	90	7 2			Red-brown, CLAY, damp (CL)			47
48	X		1 2						48
49	X	90	3 5			As above			49
50	X		5 4			Black-gray, silty, SAND and GRAVEL, damp (SW)			50
51	X	90	5 5						51
52	X		5 20			As above, brown-gray			52
53	X	80	25			Gray-green, sandy, GRAVEL, wet (GW)			53
54	X								54
55	X		25			As above			55
56	X		32 50		SM002TB01-5557				56
57	X	20	29			Bottom of boring 57 ft			57
58									58
59									59
60									60

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB02
BORING LOCATION SWMU 002	DRILLING (ft-bgs) N/A	G.S. ELEV. 649.451
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 853.97613	START DATE 10/22/96
LOGGED BY B. Squire	EASTING -3085.37841	FINISH DATE 11/4/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
0–2		75	10, 15, 17, 17	0	SM02TB02-0002	Brown clay and fine sand, some rock fragments, stiff, low plasticity, damp to moist, (fill) Black fine grain sludge and rock fragments, little well rounded gravel, bright red mottles, med. dense to dense, damp, (fill)			1, 2
2–4		50	39, 32, 41, 19	0		Black fine to coarse grain sludge, some gravel, rock fragments, layer of slag, little clay, bright red mottles, med. dense, damp, (fill)			3, 4
3–5					SM02TB02-0305				
4–5						Brown clay, little v. fine sand, little gravel, (fill)			5
4–6		50	5, 6, 7, 8	0					
5–6						Black, brown, green clay and sludge (stiff, damp) with orange- white-gray fine grained material, solid, dry, (fill)			6
6–7						White grading to yellow grading to pink-gray fine to coarse grain granular material, loose, damp, (fill)			7
6–8		50	1, 2, 1, 2	0		Black clay sludge, med. stiff, damp, (fill)			8
8–10		75	10, 14, 10, 58	0		Top - Black-brown fine to coarse grain sludge, thin layer of bright red fine grain granular material; Mid - black v. fine grain sludge; Btm - brown clay and rock fragments, (fill)			9, 10
10–12		75	9, 11, 13, 5	0	SM02TB02-1012	Red and brown-black clay, little yellow fine sand, some med. to coarse gravel, med. stiff, moist, (fill)			11, 12

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB02
BORING LOCATION SWMU 002	DRILLING (ft-bgs) N/A	G.S. ELEV. 649.451
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 853.97613	START DATE 10/22/96
LOGGED BY B. Squire	EASTING -3085.37841	FINISH DATE 11/4/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
12–14	X	0	10, 11, 10, 10			No recovery			12–14
14–16	X	50	3, 10, 5, 2	0		Brown-black fine sandy clay, some fine gravel, thin layer of red material, glass, soft, med. plasticity, moist; Mid - orange-yellow material and fine sandy clay, little gravel, soft, moist; Btm - black ashen material, fine sand to med. gravel size, loose, damp, (fill)			14–16
16–18	X	75	2, 1, 2, 1	0	SM02TB02-1618	Maroon and black iron oxide, fine sand to med. gravel size, loose to med. dense, saturated grading to wet, (fill)			16–18
18–21					SM02TB02-1820	Hydropunch perched water sample			18–21
21–23	X	0	1, 2, 1, 2	0		No recovery			21–23
23–24	X		1, 1			Maroon and black iron oxide, fine sand to med. gravel size, loose, saturated, (fill)			23–24

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB02
BORING LOCATION SWMU 002	DRILLING (ft-bgs) N/A	G.S. ELEV. 649.451
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon		START DATE 10/22/96
LOGGED BY B. Squire	NORTHING 853.97613 EASTING -3085.37841	FINISH DATE 11/4/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
			3		SM02TB02-2425				
25		100	4			Yellow-brown fine sand, med. dense, moist, (fill)			25
			3			Black, fine grain material, loose "soup", saturated			
26			4						26
			3						
27		75	3			Yellow-brown fine sand, med. dense, moist to wet, (fill)			27
			1			Red-brown v. fine sandy clay, soft to med. stiff, slightly sticky, med. plasticity, damp to moist, (fill)			
28			1						28
			1						
29		50	1						29
			1			Red-brown grading to brown sludge, occ. bright red mottles, soft, med. plasticity, moist, (fill)			
30			2						30
			1						
31		75	2			Brown sludge, v. soft, med. plasticity, moist, (fill)			31
			1						
32			1						32
			1						
33		50	2						33
			wr/24						
34									34
35		100				As above, soft to med. stiff, moist grading to damp, chemical odor, (fill)			35
			1						
36			1						36

NOTES:
1. Depths and Elevations in feet unless otherwise noted
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3. wh-weight of hammer
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6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB02
BORING LOCATION SWMU 002	DRILLING (ft-bgs) N/A	G.S. ELEV. 649.451
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 853.97613	START DATE 10/22/96
LOGGED BY B. Squire	EASTING -3085.37841	FINISH DATE 11/4/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
			1						
37		100	2			As above, with layers of yellow-brown silty sludge, soft to med. stiff, damp, (fill)			37
			1						
38			1						38
			1						
39		100	2			As above, soft, moist, chemical odor, (fill)			39
			wr/24						
40									40
41		100		13.3		As above, soft, wet grading to damp to moist, (fill)			41
			1						
42			1						42
			1						
43		75	1	23		As above, damp to moist			43
			1						
44			2						44
			1						
45		100	2	60.1					45
			1						
46			2						46
			1						
47		100	2	86.6					47
			4		SM02TB02-4749	Brown clay, v. soft grading to med. stiff, saturated grading to moist/ damp, (fill)			
48			16						48

NOTES:
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6. ft-msl-feet above mean sea level

ICF KAISER ENGINEERS

BORING LOG

PROJECT NAME Bayer Corp., New Martinsville, WV	WATER LEVELS	BORING SM002-TB02
BORING LOCATION SWMU 002	DRILLING (ft-bgs) N/A	G.S. ELEV. 649.451
DRILLING FIRM Pennsylvania Drilling Co.	WELL LEVEL (ft-msl) N/A	CASING ELEV. N/A
DRILLING METHOD Hollow Stem Auger/Split Spoon	NORTHING 853.97613	START DATE 10/22/96
LOGGED BY B. Squire	EASTING -3085.37841	FINISH DATE 11/4/96

DEPTH	S.S. SAMPLE	RECOVERY (percent)	BLOW COUNT (per 6 in.)	HNu Reading (ppm)	ANALYTICAL SAMPLE ID	MATERIAL DESCRIPTION	SYMBOL	REMARKS	DEPTH
		100	37	334.1	SM02TB02-4749	Black tar-like material with small fibers, little gravel, soft, moist, (fill)			
			50/4			Med. to coarse gravel, fine to coarse sand, little clay, med. dense to loose, (fill)			
49			47			Brown, silty sludge, v. soft, low to med. plasticity, saturated			49
			54						
50		85	35		SM02TB02A-5052	Brown, fine to coarse gravel, some fine to coarse sand, dense, saturated, (GW)			50
			29						
51			20			Black-gray-brown, fine to coarse sand and fine to coarse gravel, little silt, med. dense to dense, wet to saturated (SW/GW)			51
			21						
52		75	25						52
			14						
53		100	16		SM02TB02A-5355	Brown, fine to coarse sand and fine to coarse, well rnd gravel, dense, wet (SW/GW)			53
			18						
54			32						54
			30						
55						Hydropunch groundwater sample			55
56									56
57									57
58					SM02TB02-5860				58
59									59
60						Bottom of boring 60 ft			60

NOTES:
1. Depths and Elevations in feet unless otherwise noted
2. USCS Classification based on visual-manual procedures
3. wh-weight of hammer
4. wr-weight of rods
5. ft-bgs-feet below ground surface
6. ft-msl-feet above mean sea level

APPENDIX C

MFG SOP #7

MFG, Inc.

STANDARD OPERATING PROCEDURE No. 7

MONITORING WELL DEVELOPMENT

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol to be followed during the development of groundwater monitoring wells. Monitoring wells must be developed before they are used to collect groundwater samples. The procedures presented are intended to be general in nature. As site-specific conditions become known, appropriate modifications of the procedures may be made when approved in writing by the MFG Project Manager.

2.0 PROCEDURES

2.1 Development Procedure

After construction of the monitoring well is complete, the well will be developed by surging, bailing and/or pumping (e.g., positive displacement hand pump, electric pump or pneumatic pump). At least 24 hours must pass between completion of grouting of the monitoring well and development to allow sufficient curing of the grout.

The total depth of the well will be measured in accordance with the procedures described in the MFG SOP entitled WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT. The presence of sediment at the bottom of the well will be checked using a stainless steel bailer or positive displacement hand pump. Water and sediment will first be removed from the bottom of the well to ensure that the entire screened interval is open for water to flow into the well. The well should be bailed or pumped until the water removed from the bottom of the well is relatively free of sediment. If a bailer is used, care must be taken to avoid breaking the bottom cap on the well casing.

After most of the sediment has been removed from the bottom of the well, a well development pump (positive displacement hand pump, electric pump or pneumatic pump) should be used to remove water from the well. Initially, the intake of the pump should be at the bottom of the well. The pump intake should be raised in two- to three-foot increments to the top of the water column after approximately one-half of a casing volume of water has been removed from each interval.

Next, a surge block constructed of non-reactive material (usually stainless steel or PVC) should be used to develop the well screen by forcing water in and out of the screened area. The surge block should be moved up and down in one-to two-foot increments creating a suction action on the upstroke and a pressure action on the downstroke. Development should begin at the top of the water column and move progressively downward to prevent the surge block from becoming sand locked. After surging to the bottom of the well, the surge block should be moved progressively upward to the top of the water column.

If necessary, water may be added to the well to facilitate surging. This water should be distilled deionized or "clean" potable municipal water. The volume of de-ionized water added to the well should be noted on the Well Development Record form (Figure SOP-7-1).

After surging, the surge block should be removed and replaced with the pump or bailer. The intake of the pump or bailer should be at the bottom of the well to remove any sediment that may have collected in the bottom of the well. The pump intake should again be raised in two- to three-foot increments to the top of the water column after approximately one-half of a casing volume of water has been removed from each interval.

During development, the pH, specific conductance and temperature of the purge water should be periodically measured and documented on a Well Development Record form. Parameter readings should be collected and noted for every casing volume of water removed from the well.

The well should be alternately surged and pumped until the field water quality parameters have stabilized to within 10% for specific conductance, 0.05 pH units for pH, and 1EC for temperature, and the water is relatively clear and free of sediment.

Water removed during well development should be temporarily stored in steel drums, a portable storage tank or other approved storage container. Final disposal of all water generated during development procedures will be conducted in accordance with all legal requirements and with procedures discussed in the MFG SOP entitled STORAGE AND DISPOSAL OF SOIL, DRILLING FLUIDS, AND WATER GENERATED DURING FIELD WORK.

2.2 Documentation and Records Management

A Well Development Record will be filled out by the MFG Field Geologist for each well developed. The Well Development Record will be submitted to the MFG Project Manager. Also, the daily events and other items not covered in the Well Development Record will be entered on a Daily Field Record form in accordance with the procedures contained in the MFG SOP entitled FIELD DOCUMENTATION.

3.0 QUALITY ASSURANCE/QUALITY CONTROL

3.1 Equipment Cleaning

All reusable equipment used in developing the monitoring well should be cleaned prior to and following use. Cleaning shall be accomplished by either (1) washing with a laboratory-grade detergent/water solution, rinsing with clean, potable, municipal water, then rinsing with distilled or deionized water; or (2) steam cleaning followed by rinsing with distilled or deionized water. An acid rinse (0.1 N HCl) or solvent rinse (i.e., hexane or methanol) may be used to supplement these cleaning steps if tarry or oily deposits are encountered. The acid or solvent rinse will be followed by thoroughly rinsing with water. After final cleaning, equipment will be packaged and sealed in plastic bags or other appropriate containers to minimize contact with dust or other contaminant when not in use.

3.2 Records Review

The Project Manager or designated QA reviewer will check and verify that documentation has been completed and filed per this procedure.

APPENDIX D

ASTM 4050-91 PUMPING TEST

Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems[1]

This standard is issued under the fixed designation D 4050; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes the field procedure for selecting well locations, controlling discharge or injection rates, and measuring water levels used to analyze the hydraulic properties of an aquifer or aquifers and adjacent confining beds.

1.2 This test method is used in conjunction with an analytical procedure such as Test Method D 4105 or D 4106 to determine aquifer properties.

1.3 The appropriate field and analytical procedures are selected as described in Guide D 4043.

1.4 The values stated in SI units are to be regarded as standard.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4043 Guide for Selection of Aquifer-Test Field and Analytical Procedures in Determination of Hydraulic Properties by Well Techniques[2]

D 4105 Test Method (Analytical Procedure) for Determining Transmissivity and Storativity of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method[2]

D 4106 Test Method (Analytical Procedure) for Determining Transmissivity and Storativity of Confined Nonleaky Aquifers by the Theis Nonequilibrium Method[2]

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *aquifer, confined*—an aquifer bounded above and below by confining beds and in which the static head is above the top of the aquifer.

3.1.2 *confining bed*—a hydrogeologic unit of less permeable material bounding one or more aquifers.

3.1.3 *control well*—well by which the head and flow in the aquifer is changed, for example, by pumping, injection, or imposing a constant change of head.

3.1.4 *hydraulic conductivity (field aquifer tests)*—the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

3.1.5 *observation well*—a well open to all or part of an aquifer.

3.1.6 *piezometer*—a device so constructed and sealed as to measure hydraulic head at a point in the subsurface.

3.1.7 *specific storage*—the volume of water released from or taken into storage per unit volume of the porous medium per unit change in head.

3.1.8 *storage coefficient* —the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness. For an unconfined aquifer, the storage coefficient is approximately equal to the specific yield.

3.1.9 *transmissivity*—the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer.

3.1.10 For definitions of other terms used in this test method, see Terminology D 653.

4. Summary of Test Method

4.1 This test method describes the field practices in conducting withdrawal and injection well tests. These methods involve withdrawal of water from or injection of water to an aquifer through a control well and measurement of the water-level response in the aquifer. The analysis of the data from this field practice is described in standards such as Test Methods D 4105 and D 4106.

5. Significance and Use

5.1 Withdrawal and injection well test field procedures are used with appropriate analytical procedures in appropriate hydrogeological sites to determine transmissivity and storage coefficient of aquifers and hydraulic conductivity of confining beds.

6. Apparatus

6.1 Various types of equipment can be used to withdraw or inject water into the control well, measure withdrawal and

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved June 15, 1991. Published August 1991.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

injection rates, and measure water levels. The test procedure may be conducted with different types of equipment to achieve similar results. The objectives to be achieved by the use of the equipment are given in this section and in Sections 7 and 8.

6.2 *Control Well*—Discharge or injection well test methods require that water be withdrawn from or injected into a single well. This well, known as the control well, must be drilled and completed such that it transmits water to or from the aquifer (usually the entire thickness of the aquifer) at rates such that a measurable water level change will occur at observation wells. The control well should be as efficient as possible, to reduce the head loss between the aquifer and the well. Well development should be as complete as possible to eliminate additional production of sand or silt and consequent changes in well efficiency and pumping water levels during the test. The cuttings from the control well should be described and recorded according to Practice D 2488. The analytical method selected for analysis of the data may specify certain dimensions of the control well such as screen length and depth of screen placement. Specific requirements for control wells may be given in standards for specific analytical methods (see, for example, Test Methods D 4105 and D 4106).

6.3 *Observation Wells or Piezometers*—Numbers of observation wells and their distance from the control well and their screened interval may be dependent upon the test method to be employed. Refer to the analytical test method to be used for specifications of observation wells (see, for example, Test Methods D 4105 and D 4106).

6.4 *Control Well Pump*—A pump capable of withdrawal of a constant or predetermined variable rate of water from the control well. The pump and motor should be adequately sized for the designed pumping rate and lift. The pump or motor must be equipped with a control mechanism to adjust discharge rate. In the case of diesel-, gasoline-, or natural-gas-fueled engines, throttle settings should allow for small adjustments in pumping rates. Pumps equipped with electric motors are usually controlled by adjusting backpressure on the pump through a gate valve in the discharge line. Take care to select a discharge rate small enough such that the rate can be maintained throughout the test without fully opening the gate valve. If neither method of control is practical, split the discharge and route part of the discharge back to the well through a separate discharge line.

6.5 Many aquifer tests are made at "sites of opportunity," that is, using existing production wells as the control well and using other existing wells for observation of water level. In such cases the locations and screened intervals of the wells should be compatible with the requirements of the method of test analysis.

6.6 *Water-Level Measurement Equipment*—Manual measurements can be made with a steel tape or electric tape as described in Test Method D 4750, with a mechanical recorder linked to a float, or combination of pressure transducer and electronic data logger.

6.6.1 *Mechanical Recorders*—Mechanical recorders employ a float in the well to produce a graphic record of water level changes. Early in the test, it may be difficult to distinguish small increments of time on the recorder chart, therefore the recorder should be supplemented with additional early time measurements or by marking the trace of an automatic water-level recorder chart and recording the time by the mark. Check the mechanical recorder periodically throughout the test using the steel tape.

6.6.2 *Pressure Transducers and Electronic Data Loggers*—A combination of a pressure transducer and electronic data logger can provide rapid measurements of water-level change, and can be programmed to sample at reduced frequency late in the test. Select the pressure transducer to measure pressure changes equivalent to the range of expected water level changes. Check the transducer in the field by raising and lowering the transducer a measured distance in the well. Also check the transducer readings periodically with a steel tape.

7. Conditioning

7.1 *Pre-Test Procedures:*

7.1.1 *Selecting Aquifer-Test Method*—Develop a conceptual model of the site hydrogeology and select the appropriate aquifer test method according to Guide D 4043. Observe the requirements of the selected test method with regard to specifications for the control well and observations wells.

7.1.2 *Field Reconnaissance*—Make a field reconnaissance of the site before conducting the test to include as much detail as possible on depth, continuity, extent, and preliminary estimates of the hydrologic properties of the aquifers and confining beds. Note the location of existing wells and water-holding or conveying structures that might interfere with the test. The control should be equipped with a pipeline or conveyance structure adequate to transmit the water away from the test site, so that recharge is not induced near the site. Make arrangements to ensure that nearby wells are turned off well before the test, and automatic pump controls are disabled throughout the anticipated test period. Alternately, it may be necessary to pump some wells throughout the test. If so, they should be pumped at a constant rate, and not started and stopped for a duration equal to that of the test before nor should they be started and stopped during the test.

7.1.3 *Testing of Control Well*—Conduct a short term preliminary test of the control well to estimate hydraulic properties of the aquifer, estimate the duration of the test and establish a pumping rate for the field procedure.

7.1.4 *Testing Observation Wells*—Test the observation wells or piezometers prior to the aquifer test to ensure that they are hydraulically connected to the aquifer. Accomplish this by adding or withdrawing a known volume of water (slug) and measure the water-level response in the well. The resultant response should be rapid enough to ensure that the water level in the piezometer will reflect the water level in the aquifer during the test. Redevelop piezometers with unusually sluggish response.

7.1.5 *Measuring Pre-Testing Water-Level Trends*—Measure water levels in all observation wells prior to start of pumping for a period long enough to establish the pre-pumping trend. This period is at least equal to the length of the trend. The trend in all observation wells should be similar. A well with an unusual trend may reflect effects of local disturbances in the hydrologic system, or may be inadequately developed.

7.1.6 *Selecting of Pumping Rate*—Select the pumping rate, on the basis of the preliminary test (see 7.1.3), at which the well is to be pumped, such that, the rate can be sustained by the pump for the duration of the test. The rate should not be so large that the water level is drawn down below the perforations in the control well, causing cascading water and entrained air in the well. Under no circumstances should the rate be so large that the water level is drawn down to the water-entry section of the pump or tailpipe.

8. Procedure

8.1 *Withdrawing or Injecting Water from the Aquifer*—Regulate the rate at which water is withdrawn from, or injected into, the control well throughout the test. The short-term discharge should not vary more than 10 % about the mean discharge. For constant-discharge tests, long-term variation of discharge from the beginning to end of test generally should be less than 5 %.

8.2 Measure discharge frequently, for example every 5 min, and if necessary adjust discharge during the beginning of the test. When the discharge becomes more stable, reduce the frequency of adjustments and check discharge at least once every 2 h throughout the test. Variations in electric line load throughout the day will cause variations in discharge of pumps equipped with electric motors. Changes in air temperature and barometric pressure will likewise affect diesel motors. Late in a lengthy test, measure and adjust discharge much more frequently than the water levels are measured.

8.3 *Measuring Water Level; Frequency of Measurement*—Measure water levels in each observation well at approximately logarithmic intervals of time. Measure at least ten data points throughout each logarithmic interval. A typical measurement schedule is listed in Table 1.

8.4 *Duration of Pumping Phase of Test*—Make preliminary analysis of the aquifer-test data during the test using the appropriate test method (such as Test Methods D 4105 and D 4106). Continue the test until the analysis shows adequate test duration.

8.5 *Measuring Recovery of Water Levels:*

8.5.1 The recovery of water levels following pumping phase should be measured and recorded for a period of time equal to the pumping time. Analyze the recovery data to determine the hydraulic parameters of the system. The frequency of measuring water levels should be similar to the frequency during the pumping phase (see Table 1).

8.5.2 If water level data during the early part of the recovery phase are to be used from the control well, the pump should be equipped with a foot valve to prevent the column pipe fluid from flowing back into the well when the pump is turned off.

8.6 *Post-Testing Procedures:*

8.6.1 Tabulate water levels, including, pre-pumping water levels, for each well or piezometer, date, clock time, time since pumping started or stopped, and measurement point (Test Method D 4750).

8.6.2 Tabulate measurements of the rate of discharge or injection at the control well, date, clock time, time since pumping started, and method of measurement.

8.6.3 Prepare a written description of each well, describing the measuring point, giving its altitude and the method of obtaining the altitude, and the distance of the measuring point above the mean land surface.

8.6.4 Make plots of water-level changes and discharge measurements as follows:

8.6.4.1 Plot water levels in the control well and each observation well against the logarithm of time since pumping began. Plot the rate of discharge, Q, of the control well on arithmetic paper.

8.6.4.2 Prepare a plot of the log of drawdown, s, versus the log of the ratio of time since pumping began, t, to the square of the distance from the control well to the observation well, r, that is $\log_{10}s$ versus $\log_{10}t/r^2$, on a single graph and maintain the graph as the test progresses. Unexpected, rapid deviations of the data from the type curves may be caused by variations in discharge of the control well, or by other wells in the vicinity starting, stopping or changing discharge rates, or by other changes in field conditions. Such interfering effects may need to be measured, and adjustments made in the final data, or it may be necessary to abort the test.

8.6.4.3 *Plot Recovery of Water Levels*—Plot recovery data, consisting of plots of water level versus log of the ratio of time since pumping started (t) to the time since pumping stopped (t'). Prepare mass plots of log of recovery versus log of the quantity: ratio of time since pumping stopped (t') to the square of the distance from the control well to the observation well (r^2), that is $\log_{10}t$ versus $\log_{10}t'/r^2$.

9. Report

9.1 Prepare a report containing field data including a description of the field site, plots of water level and discharge with time, and preliminary analysis of data.

9.1.1 An introduction stating purpose of the test, dates and times water-level measurements were begun, dates and times discharge or injection was begun and ended, and the average rate of discharge or injection.

9.1.2 The "as built" description and diagrams of all control wells, observation wells, and piezometers.

9.1.3 A map of the site showing all well locations, the distances between wells, and location of all geologic boundaries or surface-water bodies which might effect the test.

9.1.3.1 The locations of wells and boundaries that would affect the aquifer tests need to be known with sufficient accuracy to provide a valid analysis. For most analyses, this means the locations must provide data points within plotting accuracy on the semilog or log-log graph paper used in the analysis. Radial distances from the control well to the observation wells usually need to be known within ±0.5 %. For prolonged, large-scale testing it may be sufficient to locate wells from maps or aerial photographs. However, for small-scale tests, the well locations should be surveyed. All faults, streams, and canals or other potential boundaries should be located. When test wells are deep relative to their

TABLE 1 Typical Measurement Frequency

Frequency, One Measurement Every:	Elapsed Time, For the First:
30 s	3 min
1 min	3 to 15 min
5 min	15 to 60 min
10 min	60 to 120 min
20 min	2 to 3 h
1 h	3 to 15 h
5 h	15 to 60 h

spacing it may be necessary to conduct well-deviation surveys to determine the true horizontal distance between well screens in the aquifer.

9.1.4 Include tabulated field data collected during the test.

10. Precision and Bias

10.1 It is not practicable to specify the precision of this test method because the response of aquifer systems during aquifer tests is dependent upon ambient system stresses. No statement can be made about bias because no true reference values exist.

11. Keywords

11.1 aquifers; aquifer tests; discharging wells; drawdown; ground water; hydraulic conductivity; injection wells; recovery; storage coefficient; transmissivity

MFG, Inc.

STANDARD OPERATING PROCEDURE No. 14

HYDRAULIC TESTING

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol to be followed during performance of a constant-discharge pumping test or a "slug test." The procedures presented herein are intended to be general in nature; as the work progresses and when warranted, appropriate revisions may be made when approved in writing by the MFG Project Manager.

2.0 PROCEDURES

2.1 Constant-Discharge Test

The performance of a constant-discharge pumping test involves three phases: 1) pre-test measurements; 2) pumping portion of the test; and 3) recovery portion of the test. Pre-test measurements include water level measurements which indicate water level trends in the test area. These effects must be accounted for when test data are analyzed. The pumping portion of the test involves monitoring water levels in the pumping well and observation wells while the discharge in the pumping well is kept fairly constant. Groundwater samples may be collected during this phase. The recovery portion of the test occurs after pumping is stopped and involves the measurement of recovery water levels in the pumped well and observation wells.

2.1.1 Pre-Test Measurements

2.1.1.1 Water Level Measurements

Prior to conducting a pumping test, water level measurements should be taken in the pumped well and all observation wells (other monitoring wells and piezometers) to be monitored during the test to describe the pre-test potentiometric surface and its natural variability (refer to MFG SOP entitled WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT). Measurements in both the pumped well and observation wells should be taken at least every 4 hours for a minimum of three days before the pumping test begins. More frequent water level measurements in one or more wells using a continuous recording device may be used to substitute for the 4-hour measurement requirement in the pumped well and all observation wells.

Prior to beginning the pumping test, watches, the datalogger and other timing devices to be used in the test should be synchronized.

The water level measurements will be made with an electric water level probe, steel surveyors' tape or continuous recording device (Stevens recorder or pressure transducer/recorder). Accuracy of water level measurements prior to and during the aquifer test will be to within plus or minus 0.02-foot in the observation wells.

An observation well may be monitored continuously with a Stevens Type F water level recorder or a pressure transducer/recorder.

If water levels are measured by hand, all pre-test water level measurements for the pumping well and observation wells will be recorded on a Pumping Test Record form (Figure SOP-14-1). The same form will be used during the pumping portion of the pumping test.

2.1.1.2 Barometric Measurements

A record of barometric changes in the vicinity of the pumping test site shall be obtained for the pre-test and test period. This record will be used to monitor changes in water levels caused by barometric effects. A recording barograph or record from a nearby weather station is acceptable.

2.1.2 Pumping Portion of Test

2.1.2.1 Measurements to be Taken

During the pumping portion of the pumping test, the following measurements will be made: 1) water levels in both the pumped well and the observation wells; 2) instantaneous and cumulative discharge from the pumped well; and 3) time at which these measurements are made. Samples of the discharge water may also be collected periodically during the test for chemical analysis or field testing. All data will be recorded on the Pumping Test Record form (Figure SOP-14-1) for the appropriate well.

2.1.2.2 Water Levels

Pumped Well:

The water level measurements in the pumped well should be taken according to the time schedule outlined below. More frequent measurements may be used.

Time Since Pumping Started			Time Intervals	
0	-	10 minutes	0.5 - 1 minute	
10	-	15 minutes	1	minutes
15	-	60 minutes	5	minutes
60	-	300minutes	30	minutes
300	-	1440 minutes	60	minutes
1440	- shut down of pump		480	minutes (8 hours)

Observation Wells:

Stevens Type F continuous recorders or pressure transducer/datalogger may be installed in the observation wells. Water level measurements may be taken in these wells using an electric water level probe or steel surveyors' tape for calibration when the Stevens recorder or transducer/recorder is installed, and whenever the recorder chart paper is changed or the recorder is adjusted in any way. If a continuous recorder or pressure transducer/datalogger is not used, then water level measurements may be taken using an electric water level probe or steel surveyor's tape according to the following schedule:

Time Since Pumping Started			Time Intervals
0	-	60 minutes	1 minute
60	-	120 minutes	5 minutes
120	-	240 minutes	10 minutes
240	-	360 minutes	30 minutes
360	-	1440 minutes	60 minutes
1440	-	shut down of pump	480 minutes (8 hours)

The time of measurements and water level measurement will be entered in the appropriate columns of the Pumping Test Record form (Figure SOP-14-1) for the pumped well and observation wells. If a Stevens recorder or pressure transducer/recorder is used, water level calibration and pertinent notes will be entered on the Pumping Test Record form.

2.1.2.3 Discharge Rate

Discharge from the pumped well will be measured using either of the following methods: 1) totalizing flow meter and stopwatch; 2) circular orifice meter; 3) Venturi meter; 4) Parshall flume; or 5) calibrated container and stopwatch. The discharge reading and time of reading will be entered on the Pumping Test Record form for the pumped well.

Discharge should be maintained within plus or minus 5 percent of the designated rate by means of a globe valve or other throttling device. Discharge will be checked and adjusted, if necessary, every 10 minutes during the first hour of pumping, at 30-minute intervals for the following 5 hours, and at one-hour intervals thereafter. Time of measurement and rate of discharge will be entered on the Pumping Test Record form for the pumped well (Figure SOP-14-1). If the pump is driven directly by an engine, the engine speed (in RPM) should be checked and noted every hour during the test. If the pump is run by an engine or a generator, the fuel level and the oil level in the engine or generator will have to be checked periodically, and fuel and/or lubricating oil added when necessary.

2.1.3 Sampling of Discharge Water

Samples of discharge water from the pumped well may be collected at time intervals specified by the MFG Project Manager, provided such sampling does not interfere with water level measurements. The temperature, pH, and specific conductance of the samples will be measured in the field when the samples are collected. The samples will be preserved for subsequent chemical analysis by an authorized laboratory in accordance with the MFG SOP entitled WATER QUALITY SAMPLING. The time the samples were collected and field measurements of water quality parameters will be recorded on the Pumping Test Record form (Figure SOP-14-1) for the pumped well.

2.1.4 Duration of Pumping

The target duration of the pumping portion of each pumping test will be established prior to beginning the test. During the test, time-drawdown and/or distance-drawdown curves for the observation wells may be plotted on semi-logarithmic paper to assist in evaluating if the test is running well and deciding on the time that the pump should be shut off. If the plots indicate steady-state conditions (e.g., the interception of a recharge source), the test may be ended before its target duration. The pumping portion of the test may be extended, at the discretion of the MFG Project Manager, to evaluate hydrologic boundaries or other transient conditions.

2.1.5 Aborted Test

Failure of pumping operations for a period greater than one (1) percent of the elapsed pumping time will require suspension of the test until the water level measured in the pumped well has recovered to within two (2) percent of the total drawdown in the pumped well during pumping. Recovery in the pumped well will also be considered complete after the well has not been stressed for a period at least equal to the elapsed pumping time of the aborted test, or if any three successive water level measurements, at least 30 minutes apart, show no further rise in the water level in the pumped well. When recovery is complete, the pumping portion of the test may be resumed.

2.1.6 Recovery Portion of Test

After the pumping portion of the test has been completed, the pump will be shut off. Water level measurements will then be taken in the pumped well and observation wells in accordance with the schedule presented below:

Time Since Pumping Stopped			Time Intervals	
0	-	15 minutes	1	minute
15	-	60 minutes	5	minutes
60	-	300 minutes	30	minutes
300	-	1440minutes	60	minutes
1440	-	End of test	480	minutes (8 hours)

Water level measurements will continue in the pumped well and observation wells until the water level in the pumped well has recovered to its pre-pumping level, or until a length of time equal to the pumping period has elapsed.

The water level data (water level below MP) and time at which measurement is made for each well will be entered on a Pumping Test Record form (Figure SOP-14-1), using the columns for the recovery portion of the test.

2.1.7 Pump Discharge

The water discharged from the pumped well should be prevented from entering the water-yielding zone being tested. If concentrations of chemicals in the discharged water are suspected to be above regulatory limits for discharge to natural water courses, the water from the pumped well shall be collected for appropriate treatment and/or disposal.

2.2 Slug Tests

Falling-head or rising-head permeameter tests ("slug tests") may be performed on piezometers and monitoring wells to estimate the lateral hydraulic conductivity of the water-bearing strata. Although the radius of influence (i.e., portion of the water-yielding zone tested) is smaller for a slug test than for long-term pumping tests, this testing method is often selected due to the low productivity and/or small available drawdown in wells. Another important consideration is that many locations can be evaluated with the slug test method for the same level of effort and cost of one pumping test.

2.2.1 Testing Equipment

A slug test consists of instantaneously raising or lowering the water level in a well and then monitoring the change of the water level through time. The slug tests will be performed by rapidly submerging (slug-in test) or retracting (slug-out test) a slug of known volume. A typical slug used in 2-inch wells is constructed of a sealed, 1-inch diameter, stainless steel pipe. The displacement volume of the slug will be measured prior to the test program.

A pressure transducer with an appropriate operating range will be used to measure the water levels during the slug tests. The pressure readings will be recorded and converted to feet of water above the transducer using a datalogger. The datalogger is programmed to record the water levels at one-second intervals at the beginning of a test and to logarithmically increase the sampling interval to several minutes toward the end of the test.

2.2.2 Testing Procedure

Upon arrival at a test well site, the static water level and total depth of the well will be measured with an electric water level probe or steel surveyors' tape (see the MFG SOP entitled WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT). The pressure transducer is then secured in the well to a depth below the lowest point to which the slug will be lowered. Before starting the test, sufficient time will be allowed for the water level in the well to adjust to the displacement caused by the transducer and cable, and for the transducer to equilibrate to the water temperature. During this period, the water level in the well will be monitored electronically using the datalogger and measured periodically with the electric water level probe or steel surveyors' tape to confirm that static water level conditions exist. Next, the slug will be lowered to a point just above the water level in the well and then rapidly submerged to begin the test.

As data are collected, the water levels displayed by the datalogger will be examined to monitor trends and the progress of the test. Manual water level measurements also will be taken during the test to confirm the transducer readings. Each test will proceed until the water level attains at least 95 percent recovery from the slug displacement. Following completion of the slug-in test, a slug-out test will be performed by rapidly pulling the slug out of the water and monitoring the recovery of water level in the same manner as for the slug-in test. In some cases, more than one slug-in and/or slug-out test may be performed to provide additional confirmation of the results.

2.2.3 Equipment Decontamination

Prior to the first slug test and between each test, the slugs, transducer, cable and water level probe (or steel tape) will be decontaminated in accordance with MFG SOP entitled EQUIPMENT DECONTAMINATION.

2.3 Data Analysis

2.3.1 Data Processing

The data collected by the datalogger are stored in the memory of the datalogger and then transferred to a cassette tape or to a computer in the field. If not transferred directly to a computer, these data are subsequently transferred to a computer for field data quality checks and data analysis. When transferred to computer, the data sets are transferred to files in comma-delineated ASCII format. The contents of each data file are imported to a spreadsheet program which allows the data manipulation and graphical presentation needed to calculate the hydraulic parameters of the water-yielding zone.

2.3.2 Slug Test Data Analysis

Slug tests in confined zones will be analyzed primarily by the method described by Cooper, Bredehoeft and Papadopulos (1967), whereas slug tests in semi-confined to unconfined water-yielding zones will be analyzed by the method discussed by Bouwer and Rice (1976). The Bouwer and Rice (1976) method is also applicable to confined aquifers and may be used to compare the results of the Cooper et al. (1967) method for confined aquifers.

Summary of Cooper, Bredehoeft and Papadopulos Method

Cooper et al. (1967) derived a solution using a partial differential equation for radial flow for the response of a finite-diameter well to an instantaneous "slug" of water. The method of analysis involves plotting the results of the slug test as H/H_0 versus log t (time), where:

H = head inside the well above or below the initial head at time t after injection or removal of the slug.

H_0 = head inside the well above or below the initial head at the instant of injection or removal of the slug.

The slug test plot is then compared against a set of "Type Curves" derived and published by Cooper et al. (1967) and Papadopulos, Bredehoeft and Cooper (1973), using a curve matching method, such that curves are moved parallel to H/H_0 to match each other. When the best match between the data plot and type curves is obtained, a value of t is selected at the $Tt/r_c^2 = 1$ match point. The transmissivity (T) is then calculated using the following equation:

$$T = \frac{r_c^2}{t}$$

where: r_c = radius of the well casing.

The hydraulic conductivity (K) is obtained from the T value by:

$$K = \frac{T}{b}$$

where: b = thickness of water-yielding zone.

This method assumes that the water-yielding zone is homogeneous, isotropic, and of uniform thickness, and that the tested well is screened throughout the thickness of the water-yielding zone.

Summary of Bouwer and Rice Method

Bouwer and Rice (1976) presented a procedure for analysis of slug test data from an unconfined aquifer. Based on an electrical analog, Bouwer and Rice provided a convenient set of curves relating the effective radius (R_e) to the other well dimensions. This procedure is based on a modification of the Theim equation for steady state groundwater flow.

$$K = \frac{r_c^2 \ln(R_e / r_w)}{2L} \frac{1}{t} \frac{\ln^{Y_0}}{Y_t}$$

where:

K	=	Hydraulic conductivity
L	=	Screen length
Y_o	=	Head of water at time (o)
Y_t	=	Head of water at time (t)
t	=	Time
r_c	=	Inside radius of casing
r_w	=	Radius of casing plus thickness of filter pack
R_e	=	Effective radius (value of R_e obtained from the set of curves given by Bouwer and Rice)

This method estimates the hydraulic conductivity without calculating transmissivity. The results of the slug tests are plotted as a semi-logarithmic graph of Y_t versus t. The values of Y_t, Y_o, and t are obtained from the straight-line portion of the graph, and the value of K is calculated.

If the water level fluctuates within the screened interval or below the base of the bentonite seal in the well, the following correction will be made to include the porosity of the filter pack in the cross-sectional area of the well (Bouwer and Rice (1976)):

$$r_c = \{r^2 + n(R^2 - r^2)\}^{0.5}$$

where:

- r_c = radius of the well including estimated filter pack porosity
- r = radius of the well screen
- n = estimated porosity of the filter pack
- R = radius of the bore hole

3.0 QUALITY ASSURANCE

3.1 Calculation Check

All data and calculations recorded on the Pumping Test Record will be reviewed prior to use. The reviewer will be a technically qualified hydrologist or hydrogeologist, as designated by the MFG Project Manager. Record of the calculation review will be made by the reviewers initials and date of review on the original Pumping Test Record form.

3.2 Records Review

The project manager or designated QA reviewer will check and verify that documentation has been completed and filed per this procedure.

4.0 REFERENCES

Bouwer, Herman and R. C. Rice, 1976. *A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells*. Water Resource Research, Vol. 12, No. 3, pp. 423-428, June.

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